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Bynum Reservoir
Dam, Bynum,
Montana, Teton
County, MT-1356

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

04

BYNUM RESERVOIR DAM
BYNUM, MONTANA
TETON COUNTY
MT-1356

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PREPARED FOR:

HONORABLE THOMAS L. JUDGE
GOVERNOR, STATE OF MONTANA

TETON COOPERATIVE RESERVOIR COMPANY
(OWNER AND OPERATOR)

PREPARED BY:
CH2M HILL
BELLEVUE, WASHINGTON

NOVEMBER 1980

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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the Corps, the State of Montana Department of Natural Resources and Conservation (DNRC), the Teton Cooperative Reservoir Company, and the Bynum Irrigation District, CH2M HILL inspected Bynum Reservoir Dam on October 29, 1979, under the authority of Public Law 92-367. The dam is located on Miller Creek in Teton County, about 5 miles west of Bynum, Montana.

This report was compiled from information obtained during an onsite inspection, review of construction plans, and analysis of available hydrologic information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

Bynum Reservoir Dam is owned and operated by the Teton Cooperative Reservoir Company. The reservoir is used for storage of irrigation waters.

The 60-foot-high earth dam impounds approximately 107,000 acre-feet at top of dam, assumed elevation 4181 feet National Geodetic Vertical Datum (NGVD). On the basis of criteria in U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the project is large in size. The dam is located such that its failure would endanger many lives and cause extensive property damage. Several ranch homes and buildings, agricultural land, U.S. Highway 89, the Burlington Northern Railroad tracks, and the town of Bynum could be flooded as a result of a rapid failure of Bynum Reservoir Dam. No dam breach analysis or routing of a dam breach flood was made for the downstream area; therefore, the conclusions on probable damage are based on a brief field visit and engineering judgment. The project is classified as having a high (Category 1) downstream hazard potential. Inspection criteria (Ref. 1) recommend that the Spillway Design Flood for a large-sized project with a high downstream hazard potential be the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that is reasonably possible in the region.

An estimated PMF was developed for the 32.6-square-mile drainage basin. The PMF resulting from the 72-hour storm has an estimated volume of 38,000 acre-feet and a peak flow of 50,000 c.f.s. The spillway has a maximum discharge

capacity of about 9,600 c.f.s. with the reservoir at dam crest, assumed elevation 4181 feet NGVD. The routing of the PMF was started with a reservoir storage of 80,000 acre-feet (about 2 feet below the spillway crest). Routing of the PMF and lesser floods indicates that the project can control a flood equal to approximately 93 percent of the PMF ordinates. Because the project is incapable of controlling the full PMF without overtopping and causing the dam to fail, Bynum Reservoir Dam does not meet inspection criteria. The dam is constructed of materials that would quickly erode and rapidly fail if overtopped by floodwaters. Such a failure would endanger many lives and cause property damage downstream of the dam.

A visual inspection of the dam embankment revealed neither longitudinal nor transverse cracking. Seepage and ponding water was observed in several locations near the downstream toe, but significant erosion has not occurred, and it does not appear to be a threat to embankment stability. The upstream slope has had severe wave erosion along slopes partially covered with riprap and those covered with gunite. No stability analysis of the embankment is on file. Based on a review of available information, the dam embankment may be in conformance with the embankment stability criteria in the recommended guidelines; however, sufficient information does not exist for the evaluation of stability.

The outlet conduit upstream of the gates could not be inspected during the site visit because of the reservoir level. The downstream slide gate may be inoperable. The outlet structure and basin contained cracking and exposed reinforcement.

RECOMMENDATIONS

Because of storage between normal pool and dam crest, the present project provides a certain degree of flood protection to the downstream area. The intent of report recommendations is to improve project safety while preserving the existing flood protection.

A downstream warning plan for use, in the event of possible dam overtopping or structural failure, needs to be developed. Repair concrete of outlet structure and downstream basin. Inspect outlet conduit upstream of gates and repair as necessary. Repair downstream slide gate, and operate both gates through their full operating range at least annually. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

Conduct an engineering analysis of the embankment stability, based on field investigation and laboratory testing. Investigate source of seepage and ponding water at downstream toe and modify the embankment as studies indicate. Conduct a wind wave analysis of the reservoir and modify the project as required.

Conduct periodic inspections of the project at least every 3 years by engineers experienced in dam design and construction. Prior to implementing report recommendations, the Owner is urged to coordinate with the Montana Department of Natural Resources and Conservation.

RICHARD L.
FOSTER
2646 E

Richard L. Foster
Professional Engineer

PERTINENT DATA

1. GENERAL

Federal ID No.	MT-1356
Owner/Operator	Teton Cooperation Reservoir Company
Date Constructed	1908 with subsequent additions and modifications
Purpose	Irrigation
Location	Section 32, T26N, R6W, Principal Meridian
County, State	Teton County, Montana
Watershed	Miller Creek, tributary of Muddy Creek
Downstream Hazard Potential	Category 1 (High)
USGS Quadrangle	Bynum

2. RESERVOIR

Surface Area at Spillway Crest, Elevation 4175.4 feet NGVD	3,200 acres
Drainage Area	32.6 square miles total, including 5.2-square-mile reservoir, 27.4-square-mile land
Storage at Spillway Crest, Elevation 4175.4 feet NGVD	87,000 acre-feet
Storage at Dam Crest, Elevation 4181 feet NGVD	107,000 acre-feet
Surcharge Storage	20,000 acre-feet

3. SPILLWAY

Type	Uncontrolled natural saddle

Crest Elevation	4175.4 feet NGVD
Capacity with Reservoir at Dam Crest	9,600 c.f.s.

4. OUTLET WORKS

Control Tower	Reinforced concrete
Conduit	Straight-legged horseshoe, 2.5-foot-radius top, 3.25-foot-high side walls
Conduit Length	337 feet
Gates	1--60 inches x 60 inches 1--60-inch-diameter slide gate
Capacity with Reservoir at Spillway Crest	700 c.f.s.

5. DAM

Type	Earth
Length	3,700 feet
Crest Width	15 and 20 feet
Crest Elevation	4181 feet NGVD
Hydraulic Height (crest to toe)	60 feet
Upstream Slope	1 V on 3 H lower; 1 V on 1.5 H upper
Downstream Slope	1 V on 2 H

NOTE: All elevations are based on 4185 feet NGVD as top of control tower.

Chapter 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Bynum Reservoir Dam, owned and operated by the Teton Cooperative Reservoir Company.

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-Federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many Federal and state agencies, professional engineering organizations, and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigation and evaluation of existing dam conditions, so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.

(2) based upon an evaluation of the available data and a visual inspection.

(3) performed to determine whether any needed emergency measures and/or whether if additional studies, investigations, and analyses are necessary or warranted.

(4) not intended to include extensive explorations and analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations, except for extreme emergency situations. In these cases, the Corps may proceed with Phase II studies, but only to the extent needed to answer questions relating to dam safety that cannot be answered otherwise. The two phases of investigation outlined above are intended only to evaluate project safety; they do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementing these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report are based on a brief visual inspection of the project and a detailed review of available construction plans. Inspection procedures and criteria are those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

Personnel present during the October 29, 1979, inspection include:

Richard Eckerlin, Seattle District, U.S. Army Corps of Engineers
Art Taylor, State of Montana, Department of Natural Resources and Conservation
Barnie Maltby, Bynum Irrigation District
Ken Johnson, Bynum Irrigation District
Don Rice, Teton Cooperative Reservoir Company

CH2M HILL personnel who participated in the field inspection and contributed to this report are:

Miles Bubenik, Geotechnical Engineer, Team Leader
Jerry Jacksha, Geotechnical Engineer
Loren Bottorff, Hydrologist/Hydraulics Engineer

This report has been reviewed by the State of Montana DNRC and the Teton Cooperative Reservoir Company, and their written comments are enclosed at the end of the report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Bynum Reservoir Dam is located on Miller Creek, a tributary of Muddy Creek, in Teton County, Montana. The dam is approximately 5 miles west of Bynum (see Plate 1). The dam is listed in the National Inventory of Dams as having a high (Category 1) downstream hazard potential, and its Federal identification number is MT-1356. The dam was constructed in 1908, but subsequent additions and modifications have been made. Bynum Reservoir Dam is 60 feet high, 3,700 feet long (Plate 2 and Photo 1), and impounds approximately 107,000 acre-feet at dam crest, elevation 4181 feet NGVD. (All elevations are based on an elevation of 4185 feet for the top of the outlet works control tower.)

Based on visual reconnaissance and engineering judgment, approximately five homes could be affected by a sudden breach of the dam. Agricultural land would be flooded, and flooding may occur at Bynum. In addition, U.S. Highway 89 and the Burlington Northern Railroad tracks would be flooded. On the basis of this information and in accordance with the recommended guidelines, the project size is large, and the downstream hazard potential is high (Category 1).

The 3,200-acre reservoir is used to store irrigation water. The project is owned and operated by the Teton Cooperative Reservoir Company. The Bynum Irrigation District owns controlling stock interest in the Bynum Reservoir Project.

The low-level outlet for the dam consists of a concrete straight-legged horseshoe conduit with a 2.5-foot-radius roof and 3.25-foot-high side walls. Flows are controlled by a 60- by 60-inch slide gate and a 60-inch-diameter slide gate. The spillway consists of a natural saddle about 1,200 feet west of the left abutment of the dam. The low point of the saddle is about 5.6 feet lower in elevation than the low point on the dam crest.

1.2.2 Regional Geology and Seismicity

The regional geology and seismicity were addressed in a memorandum by R. D. Eckerlin (Ref. 2). The following information is taken from that memorandum.

> Bynum Reservoir is in the Great Plains physiographic province, a region of subdued knob and kettle topography left by the stagnating glaciers that once occupied the region. The reservoir lies on the western flank of the Sweetgrass Arch and is located several miles east of the Disturbed Belt, a zone of thrusted and folded Paleozoic and Mesozoic rocks. The area is underlain by the Virgelle Sandstone Formation and soft shale (claystone) and crossbedded sandstone of the Two Medicine Formation. The Two Medicine is almost entirely continental, consisting of fluviatile and lacustrine deposits and is the most widespread unit in the area around Bynum Reservoir. These bedrock units dip gently west off the western flank of the South Arch segment of the Sweetgrass Arch.
>
> Bynum Reservoir lies in an area of moderate seismic activity. The Inspection Guidelines (Ref. 1) Seismic Zone Map of the Contiguous States shows the site in Zone 2, which has a potential for moderate earthquake damage. Although the zoning map is based on a known distribution of damaging earthquakes, it does not necessarily reflect accurate or adequate seismic design for the site. The closest historic seismicity was a magnitude 3.0 event, which occurred in 1935 about 17 miles to the east. Western Montana is seismically active along the Rocky Mountain Front. This area shows the greatest chance of producing the highest acceleration the dam would experience. The seismicity east of the front is quite diffuse, and there is no lineup of epicenters to indicate that Bynum Reservoir is in a high risk area. Algermissen (1976) estimates a 90 percent chance of a 0.04 g acceleration being experienced at this dam in a 50-year period.

1.2.3 Site Geology

The site geology and seismicity were addressed in a memorandum by R. D. Eckerlin (Ref. 2). The following information is taken from that memorandum.

> There are no known preconstruction or postconstruction geotechnical investigations.

The dam appears to be founded partly on upper Cretaceous age claystone and sandstone bedrock of the Two Medicine Formation, alpine glacial outwash, and Miller Creek alluvium. Outwash in the area consists of unsorted materials containing clay, silt, sand, gravels, and boulders, some as much as 5 to 7 feet in diameter. Alluvium consists of reworked outwash deposits and eroded bedrock.

The right (east) abutment is believed to be founded on thinly bedded sandstone and claystone bedrock. The left (west) abutment appears to be founded on outwash deposits and sandstone bedrock.

The west embankment is believed to be founded on outwash deposits.

The area around the reservoir has subdued kame-kettle topography. The shoreline is very gentle, with slopes rising less than 5 feet above maximum reservoir level. Wave erosion of the reservoir slopes occurs but is of minor consequence.

1.2.4 Design and Construction History

Bynum Reservoir project was begun about 1908 by the Teton Cooperative Reservoir Company with the construction of a 50-foot-high dam. No designs, plans, or specifications from this original work exist. In 1926, the original dam was upgraded to include a new low-level outlet tunnel, control tower, and gates, as well as a raise of approximately 10 feet on the upstream side to the present dam configuration. Design information is not known to exist and the designer is unknown; however, a few drawings and a brief set of specifications were available for review. No embankment strength information or stability analyses were on file.

Chapter 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway for Bynum Reservoir Dam is a natural, unlined saddle about 1,200 feet west of the left abutment of the dam. The saddle is 5.6 feet lower in elevation than the low point of the dam crest. There has been a small amount (approximately 1 foot deep) of excavation or erosion in the saddle. The saddle, including the approach and discharge channel, is covered with native grasses that cover silt and angular sandstone fragments. The saddle discharges flow a safe distance from the dam. A cross section of the saddle shows that the side slopes are very gradual, about 3 percent slope (Plate 3).

The discharge rating was developed by computing flow areas and velocities for various assumed critical depths. Because the saddle is very broad, it was assumed to function as a broad-crested weir with a coefficient 2.65. Therefore, the critical depth discharges were adjusted by the ratio 2.65/3.09 (3.09 being an approximate coefficient for the weir equation at critical depth). The maximum discharge capacity of the spillway with the reservoir at top of dam, assumed elevation 4185 feet NGVD, was estimated to be 9,600 c.f.s. The spillway rating curve is presented on Plate 4.

2.1.2 Outlet

The low-level outlet for Bynum Reservoir Dam is located through the eastern leg of the embankment. The present outlet works was built in about 1926 as a replacement for the original outlet works located to the west. The Bynum Irrigation District representative present at the inspection reported that, except for a short portion upstream, most of the low-level outlet was tunneled through the existing embankment. The present concrete conduit is a straight-legged horseshoe section with a 2.5-foot-radius roof and 3.25-foot-high side walls (Photo 2). Corner fillets are located at the intersection of the floor and walls. The conduit is about 337 feet long from the intake structure to the outlet structure (Plate 5).

A gate control tower is located near the axis of the dam, about 80 feet downstream from the intake structure. The intake structure could not be inspected during the site visit because it was submerged by the reservoir. Construction drawings indicate that a gate control tower was originally located at the upstream end of the conduit. The

drawings indicate that the original gate tower was left in place with only the gates removed when the present gate tower was constructed; however, no evidence of the original upstream gate tower could be observed during the site inspection. The existing gate control tower (Photo 2) is a wet well with a 60- by 60-inch upstream slide gate and a 60-inch-diameter downstream slide gate. The gate controls are exposed to the weather but appear to be in good condition. The downstream gate is left open and flows are controlled with the upstream gate. The reason for controlling flows with the upstream gate is not known. The downstream gate has not been used for several years and may now be inoperable.

Using the upstream gate as an operating gate causes a problem in servicing the gate because it cannot be worked on in-the-dry. However, potential problems also exist in using the downstream gate as the operating gate because the gate does not have a downstream air vent. Regulating flows with the downstream gate may result in problems with cavitation damage. Perhaps regulation of flows was changed from the downstream gate to the upstream gate because of a problem with the downstream gate. The conduit has an approximately 20-degree bend to the left. The concrete of the conduit was in good condition between the control tower and the outlet, and only minor cracking was observed. The conduit upstream of the control tower was submerged and could not be inspected.

The outlet structure consists of a pair of warped concrete wing walls about 20 feet long. The right (looking downstream) wing wall has a crack running its length (see Photo 5). There is also exposed reinforcement and concrete spalling. However, the cracking does not threaten the dam's integrity. A 27-foot-wide, 120-foot-long concrete basin is located immediately downstream of the wing walls (see Photos 3 and 4). This rectangular basin was built within an existing trapezoidal basin in the mid-1950's. The top of the old concrete walls can be seen protruding out of the fill outside the rectangular basin. The size of the basin is adequate for energy dissipation, but the concrete is in poor condition. The concrete floor of the basin is heavily cracked with vertical displacements of as much as 3 inches. Steel and timber braces have been placed between the walls of the basin to act as spreaders. The basin leads to an unlined irrigation canal.

The discharge rating was developed with the gates open and by assuming full conduit flow with Manning's "n" of 0.014. The maximum discharge with the reservoir at top of dam, assumed elevation 4181 feet NGVD, was estimated to be 750 c.f.s.

2.1.3 Freeboard

Flood routings (see paragraph 2.2.4) indicate that the dam overtops during the PMF and, therefore, the dam has no freeboard with the recommended spillway design flood. The vertical distance between the low point on the dam and the reservoir level at the time of the October 29, 1979, inspection was 18.8 feet. The crest of the spillway is 5.6 feet below the low point on the dam crest. The reservoir is normally filled to a level about 2 feet below the spillway crest, leaving about 7.5 feet to the crest of the dam. The effective fetch for wind-generated waves on the reservoir is about 2.2 miles. Wave runup on the embankment is estimated to be about 8 feet. The vertical distance between the crest of the dam and the normal reservoir level is not considered adequate to prevent overtopping the embankment by wind-generated waves.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 General

The climate of the area is continental in nature, characterized by warm summers and cold winters. The nearest (with a long record) climatological station (elevation 3945 feet NGVD) is at Choteau, about 15 miles southeast of the dam. Mean annual precipitation at the station is 12.1 inches, with 57 percent falling in May through July. Mean January precipitation is 0.32 inches and mean July precipitation is 3.26 inches. Mean annual precipitation on the Bynum Reservoir drainage basin may be near 20 inches. Mean annual temperature at Choteau is 43.7 degrees Fahrenheit (F); mean January temperature is 21.1 degrees F and mean July temperature is 66.3 degrees F. Temperatures on the Bynum Reservoir drainage basin may average a few degrees cooler than Choteau's. Summer temperatures can exceed 100 degrees F, and winter temperatures can dip well below 0 degrees F. Winters have few extended cold spells. Periods of warm, windy "chinook" weather occur between cold spells.

The drainage basin area for Bynum Reservoir Dam is 32.6 square miles, of which 5.2 square miles are lake area and 27.4 square miles are land area. Basin elevations vary from 4180 feet NGVD at the dam to 6430 feet NGVD on the western boundary. The land portion of the basin consists mainly of rolling grassland. There are some wooded areas in the upper portion of the basin. The basin is long (about 13 miles) and narrow. The reservoir is filled by inflow streams and by canal diversion from Muddy Creek and the Teton River.

The irrigation district measures the reservoir stage by measuring the distance from the top of the control tower to

the reservoir level in the wet well. Currently, there are no stream gages on the creeks leading into Bynum Reservoir or on other creeks in the area.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of 3,200 acres and a storage of 87,000 acre-feet at spillway elevation 4175.4 feet NGVD. Approximately 20,000 acre-feet of surcharge storage is available in the reservoir between spillway crest and dam crest. The spillway discharge with the reservoir at the dam crest is 9,600 c.f.s., about 790 acre-feet per hour.

2.2.3 Estimated Probable Maximum Flood

The inspection guidelines recommend that the Spillway Design Flood (SDF) for a project of this type be the Probable Maximum Flood (PMF). The PMF is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that is reasonably possible in the region. An estimate of the PMF was made during this dam safety analysis and was routed through the reservoir.

The procedure contained in the U.S. Weather Bureau's Technical Paper 38 (Ref. 3) was used to compute the probable maximum precipitation (PMP). This storm produces 9.9 inches in 6 hours and 15.8 inches in 24 hours. The 72-hour precipitation was estimated to be 18.5 inches. A triangular unit hydrograph for 30-minute rainfall duration was developed for the 27.4-square-mile land portion of the drainage basin by procedures outlined in Design of Small Dams (Ref. 4). A curvilinear fit of the triangular unit hydrograph was used.

A second unit hydrograph was developed for direct precipitation on the 5.2-square-mile reservoir. Frozen ground and zero losses were assumed for the entire flood. The PMP was applied to the unit hydrograph by means of the computer program, HEC-1 (Ref. 5). A base flow of 1,000 c.f.s. (actual value not available for this study) was used to account for canal inflow to the reservoir. This estimate of the PMP produced a flood with a peak flow of 50,000 c.f.s. and a volume of 38,000 acre-feet.

2.2.4 Flood Routing

The PMF was routed through the reservoir by using the computer program HEC-1 (Ref. 5). The routing was started with the reservoir storage of 80,000 acre-feet (about 2 feet below the spillway crest). This is considered full storage by the Bynum Irrigation District.

Routing studies indicate that:

- During the full PMF, the dam would be overtopped when approximately 76 percent of the flood volume enters the reservoir.
- Routings were made of hypothetical floods less than the PMF to determine the magnitude of floods the dam can control. The hypothetical hydrographs are obtained by applying percentages to the PMF ordinates. A flood with a hydrograph having ordinates corresponding to 93 percent PMF ordinates is just controlled by the project. Larger floods would overtop the dam.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam Embankment

The 60-foot-high dam is about 3,700 feet long. The main dam has a straight and angled section on the right two-thirds (about 2,600 feet) and a 15-foot-high straight-axis dam section on the left (western) portion of the dam (about 1,100 feet) (Plate 2). The crest width of the main embankment is 20 feet, and that of the westerly embankment is 15 feet. For the main dam, the upstream slopes are 1 V on 3 H, with the last 10-foot raise sloping at 1 V on 1.5 H (Plate 6). The downstream slopes are 1 V on 2 H. On the westerly portion, both the upstream and downstream slopes are 1 V on 2 H (Plate 6). The embankment is believed to be homogeneous sandy silt fill. These embankment materials would quickly erode and rapidly fail when overtopped by floodwaters.

No specifications exist for the original dam construction. A brief set of specifications for the 1926 dam upgrading and raise state that any riprap or other surfacing of the original embankment was to be removed before placing material in "horizontal layers not exceeding 6 inches in thickness, and . . . compacted by the tamping of well distributed horse teams." It was also stated that "coarser and more free-draining material be placed at the downstream toe on new embankments." The embankment material was to be disced to a maximum particle size of 2 inches and moistened sufficiently to facilitate compaction.

Our field inspection showed the downstream embankment face was a sandy silt with some angular rock and a covering of grass and brush (Photo 6). The upstream slope on the main dam section (easterly portion) was partially covered with elongated riprap estimated to vary in size between 0.5 and 3 feet. No bedding layer was found. The slope was not adequately covered to protect against wave erosion. Serious wave erosion and oversteepening had occurred in several locations (Photo 10). The upstream slope on the westerly

portion (Photo 9) was covered with a 4-inch, nonreinforced "gunite" layer. The gunite was intact and in fair condition with no major cracking, except for an area approximately 10 feet square, located 200 feet west of the angle point in the dam axis, where erosion had undermined the toe (Photo 10). In the same general area, riprap protection had been placed on the upstream gunite slope. No other significant erosion, irregularities, slumps, or cracks were found on the dam crest or slopes.

2.3.2 Foundation Conditions, Seepage, and Drainage

Both abutments are sandstone and claystone bedrock with a shallow covering of residual soil. The main dam embankment is believed to be founded on reworked outwash deposits and bedrock. Specifications indicate that the dam foundation was stripped. A 1915 drawing (Plate 7) shows that a cutoff trench up to 15 feet deep was excavated and backfilled by the puddle method (sand, gravel, and clay soil mixture deposited in water in 6-inch layers and thoroughly worked with shovels). The drawing suggests that this cutoff exists only under the highest portion of the dam (easterly portion), and its location with respect to the present dam axis is unknown.

The field inspection found several areas of seepage on the downstream slope and adjacent to the downstream toe (see Plate 2). Included is a pond (Photo 11) of clear water boiling up at an estimated 20 gpm in a depression about 60 feet below dam crest and 50 feet west of the outlet canal. Reports during the inspection indicate this ponding water results from an embankment drain and that the water level fluctuates up to 4 to 5 feet deep. All seepage was flowing clear, except for seepage near the downstream toe on the slope that had a rust color, possibly indicating the existence of a metal drain. The seepage observed was not causing significant erosion.

The construction specifications provided for embankment drains and backfill, but the few available drawings do not show any drains. The inspection did not find any drains except one, located at the headwall of the outlet tunnel portal, that was a 4-inch metal drain and flowing clear water at about 10 gpm.

The dam embankment is not instrumented.

2.3.3. Stability

Guidelines for dam safety inspections (Ref. 1) recommend that stability analyses be kept on file for all dams in the high-hazard category. There is no information on stability, strength data, construction material testing or classification,

or embankment water levels. The dam has served satisfactorily for about 70 years with no recorded embankment problems, except erosion of the upstream slope. Based on a review of available data and the field inspection, it is our judgment that embankment stability may conform with inspection guidelines; however, insufficient information is available to evaluate stability.

2.4 PROJECT OPERATION AND MAINTENANCE

Bynum Reservoir Dam is owned and operated by the Teton Cooperative Reservoir Company. There is no formal operation and maintenance program for the facility. Information on operations and maintenance was obtained through discussions with Mr. Maltby and Mr. Johnson of the Bynum Irrigation District.

2.4.1 Dam

Maintenance of the dam is performed as required. Most of the maintenance is for riprap protection on the upstream face of the dam. The Bynum Irrigation District was placing riprap at the time of the inspection. Other portions of the facility, except the outlet structure concrete, appeared well maintained.

2.4.2 Reservoir

This reservoir is used for storage of irrigation water. Water is diverted to the reservoir by canal from Muddy Creek and the Teton River. The reservoir is usually filled in the spring, and water is released as needed for irrigation. The operators consider that the reservoir is full at a storage of 79,000 acre-feet (about 12 feet below the top of the control tower, 2 feet below spillway crest). Flows through the outlet works are usually regulated by the upstream gate; the downstream gate is left fully open. The downstream gate may be frozen in position and inoperable, since it has not been opened in several years.

2.4.3 Warning System

There is no formal warning plan for use in the event of impending dam failure.

Chapter 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in terms of the recommended guidelines performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification, and Safety Evaluation

In accordance with inspection guidelines, Bynum Reservoir Dam is large in size with a high downstream hazard potential rating. The recommended Spillway Design Flood (SDF) for this project is 100 percent of the PMF. Because the project is incapable of controlling the full PMF without overtopping and causing the dam to fail, Bynum Reservoir Dam does not meet inspection criteria.

3.1.2 Embankment Dam

A visual inspection of the dam revealed neither longitudinal nor transverse cracking. Seepage was observed at the downstream toe and on the lower slope of the embankment. The seepage has not caused significant erosion.

The downstream slope was uniform, with no irregularities or slumps. The upstream slope has been severely eroded by wave attack. The partial covering of riprap on the upstream slope is not adequate to protect against erosion. Wind-generated waves could overtop and damage the embankment crest at normal pool conditions. No stability analysis of the dam embankment is on file. No information is available for foundation strength data, construction control testing, or water levels in the embankment. Based on a review of available data, the dam may conform with the recommended guidelines; however, insufficient information is available to evaluate stability.

3.1.3 Spillway and Reservoir Capacity

The reservoir has a surface area of 3,200 acres and a storage of 87,000 acre-feet at spillway elevation 4175.4 feet NGVD. Approximately 20,000 acre-feet of surcharge storage is available in the reservoir between spillway crest and dam crest. The natually lined spillway does not jeopardize dam safety as the spillway discharges a safe distance away from the dam. The spillway discharge with the reservoir at the dam crest is 9,600 c.f.s., about 790 acre-feet per hour. The lack of energy dissipation does not present a problem. The project can control a hypothetical flood having ordinates of approximately 93 percent of the PMF.

3.1.4 Outlet Works

The outlet conduit upstream of the control tower could not be inspected because of the reservoir level. The downstream slide gate may not be in operating condition, and all flows are regulated by the emergency slide gate. The concrete of the conduit (downstream of the gates) is in fair condition, but the outlet structure and basin show spalling, cracking, and exposed reinforcement. The discharges are controlled with the upstream gate, which causes a problem in servicing the gate since it cannot be worked on in-the-dry. However, potential problems also exist in using the downstream gate as the operating gate because the gate does not have a downstream air vent.

3.1.5 Operation and Maintenance

The Bynum Irrigation District has no formal operation and maintenance plan for Bynum Reservoir Dam. Maintenance is performed as required. The reservoir is filled by canal diversion, and releases are made as needed for irrigation. The Bynum Irrigation District considers the reservoir full at a storage of 80,000 acre-feet (12 feet below the top of control tower, 2 feet below spillway crest). There is no formal warning plan for use in the event of impending dam failure.

3.2 RECOMMENDATIONS

Because of storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to improve project safety, while preserving this existing flood protection.

The findings suggest that a high priority be given to the following recommendations.

1. Immediately develop, implement, and periodically test an emergency plan for alerting downstream residents in case of impending dam failure.

2. Repair concrete of the outlet structure and downstream basin.

3. Inspect outlet conduit upstream of gates and repair as necessary.

4. Repair downstream slide gate and operate both gates through their full operating range at least annually. Consideration should be given to providing an adequate air vent for the downstream gate and using this gate to regulate reservoir releases.

5. Continue to repair, as required, the upstream riprap and gunite slope to prevent erosion due to wave attack.

   Conduct a detailed wind wave analyses on the reservoir and evaluate the project's ability to withstand damage from wind-generated waves. Modify the project as studies indicate.

6. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

7. Conduct and place on file stability analyses of the dam embankment. These analyses must be performed by a qualified geotechnical engineer and be based on in situ strength properties of the foundation, embankment and abutment materials, and phreatic surface conditions. The material strength properties must be established by drilling and sampling with laboratory testing as appropriate, and the phreatic surface must be determined by installing and monitoring piezometers. Modify the embankment as studies indicate.

8. Investigate source of seepage that is adjacent to the left side of the outlet channel. Analyze effects this seepage has on project and make any necessary modifications.

9. Conduct periodic inspections of the facility at least at 5-year intervals by engineers with experience in dam design and construction.

10. Before performing engineering studies and remedial construction, coordinate the work with the State of Montana Department of Natural Resources and Conservation.

REFERENCES

1. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C., Department of the Army, May 1975.

2. Richard D. Eckerlin, U.S. Army Corps of Engineers, Memorandum on Bynum Reservoir Geologic Inspection, October 29, 1979.

3. U.S. Weather Bureau, Technical Paper 38, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Washington, D.C., 1960.

4. U.S. Bureau of Reclamation, "Design of Small Dams," 2nd Edition, 1974.

5. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, January 1973.

APPENDIX

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR
32 SOUTH EWING
STATE OF MONTANA
(406) 449-2872
HELENA, MONTANA 59601

September 19, 1980

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Attn: Ralph Morrison

Re: CH2M/Hill dam Safety Inspection Report on Bynum Reservoir Dam (MT-1356).

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for this opportunity to review and comment on the final draft report on Bynum Reservoir Dam.

Sincerely,

Richard L Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB/AT/lj

"AN EQUAL OPPORTUNITY EMPLOYER"

Teton Cooperative Reservoir Company
Bynum, Montana

Dear Sirs:

The first error in your inspection report on the Bynum Reservoir is that it does not belong to the Bynum Irrigation District, but is owned and operated by the Teton Cooperative Reservoir Company, a cooperative made up of 1,000 shares of stock divided among numerous owners.

The dam, constructed in 1908 and enlarged in 1926, is earth-filled with gravel seams packed around tile drainage pipes. The outlet to this drainage has been covered over the years and now causes a pool below the dam. The dam was filled to the crest in the spring of 1934, and did pose a threat during a high wind in late May of that year. An emergency was quickly sensed, and a number of men sand-bagged areas on the low parts of the dam's crest. Since that time the reservoir is never filled to hold over 79,000 acre-feet. In case of flood conditions this allows about 26,000 acre-feet of reserve capacity to be utilized before the spillway would become operative. I have been close to the operation of this dam for 50 years and water has never flowed out of the spillway. During the great flood of 1964 our reservoir was only filled to 1/2 of capacity.

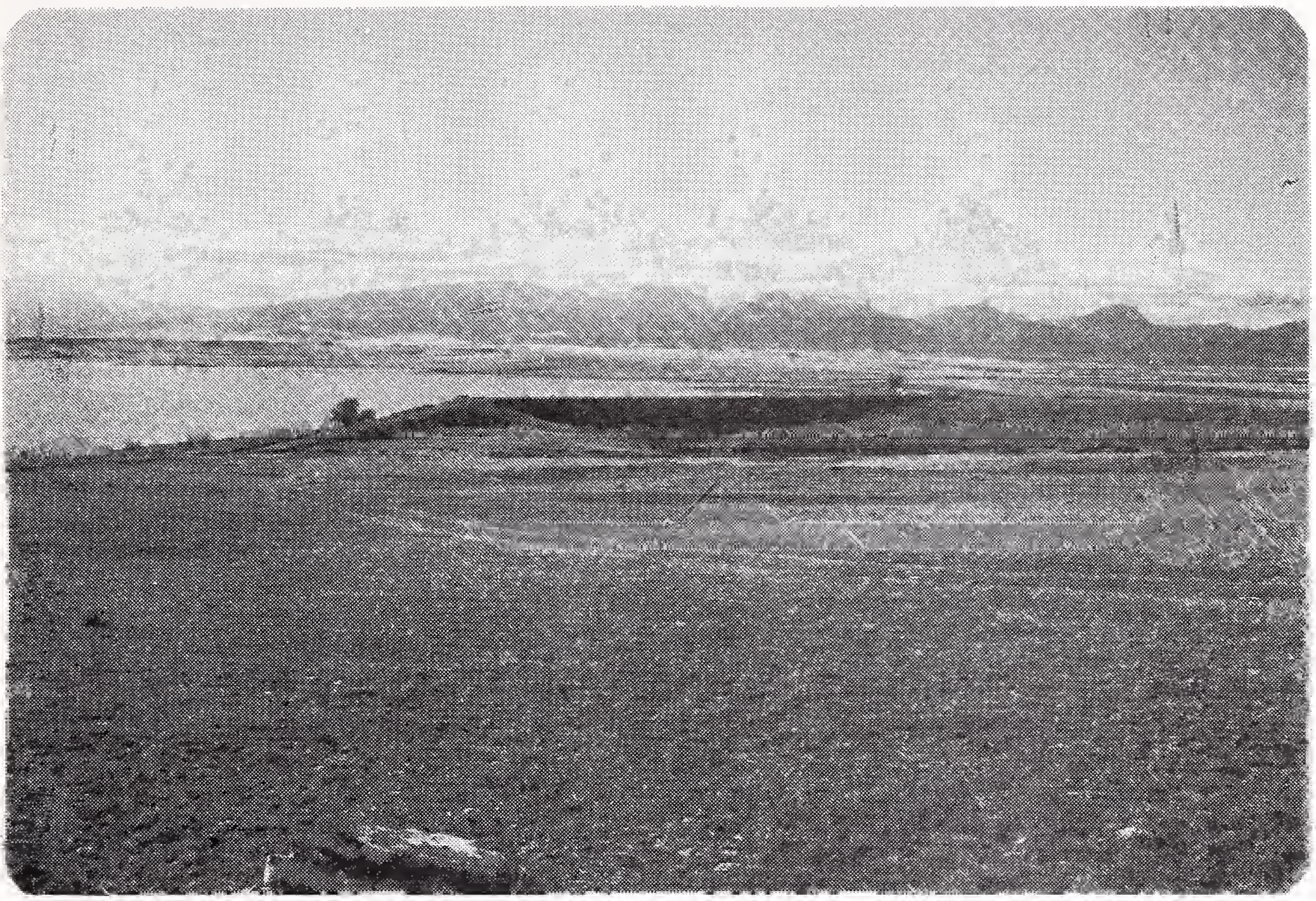
Since 1934 thousands of yards of rip-rap material have been added to the water side of the dam, and as the movement of the waves pulls it down more material has been added. Soon we hope to have created an angle of repose on the face of the dam whereby the rip-rap will become stable. Those places where you saw it eroded are being filled as well as additional material being added to other spots.

The people living in the area below the dam are cognizant of the danger involved. However, we have lessened this danger by governing the amount of water we impound, and the constant watch which is exercised at flood periods and after earthquakes (3 in the last 54 years).

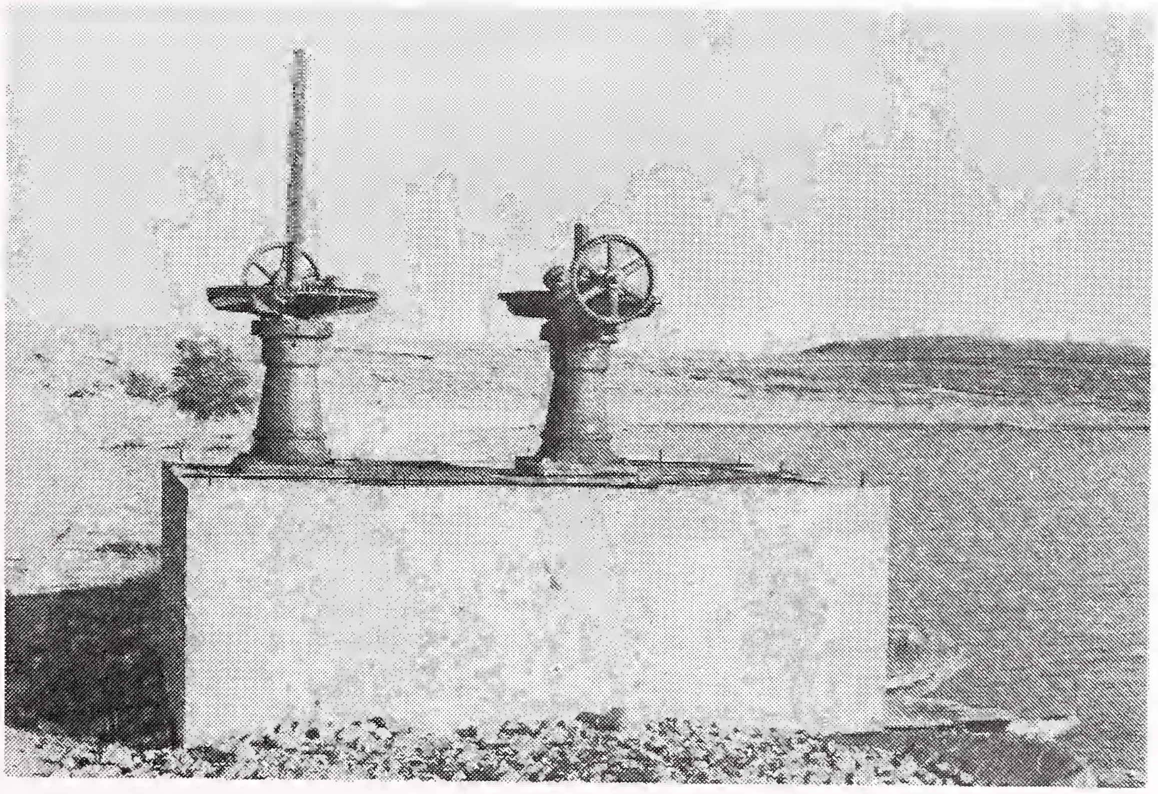
The superintendent of the works for the Teton Co-operative Reservoir, Kenneth Johnson, informed me that he had both outlet gates in operation, and that the stilling pool repair was pending.

We do appreciate your concern and suggestions in behalf of our safety and welfare, however, we do wish to inform you that we have not been entirely ignorant of our situation.

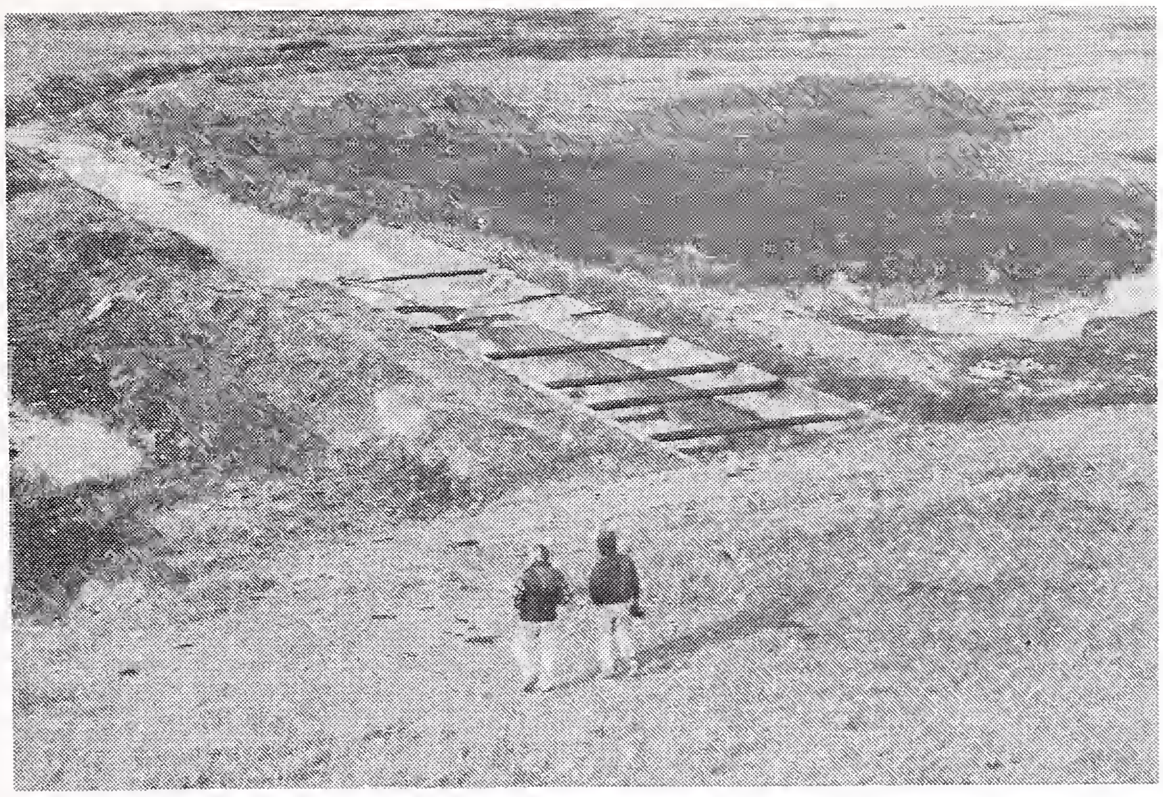
Yours truly,
Ira Perkins
Sec. of Teton Co-op. Res. Co.



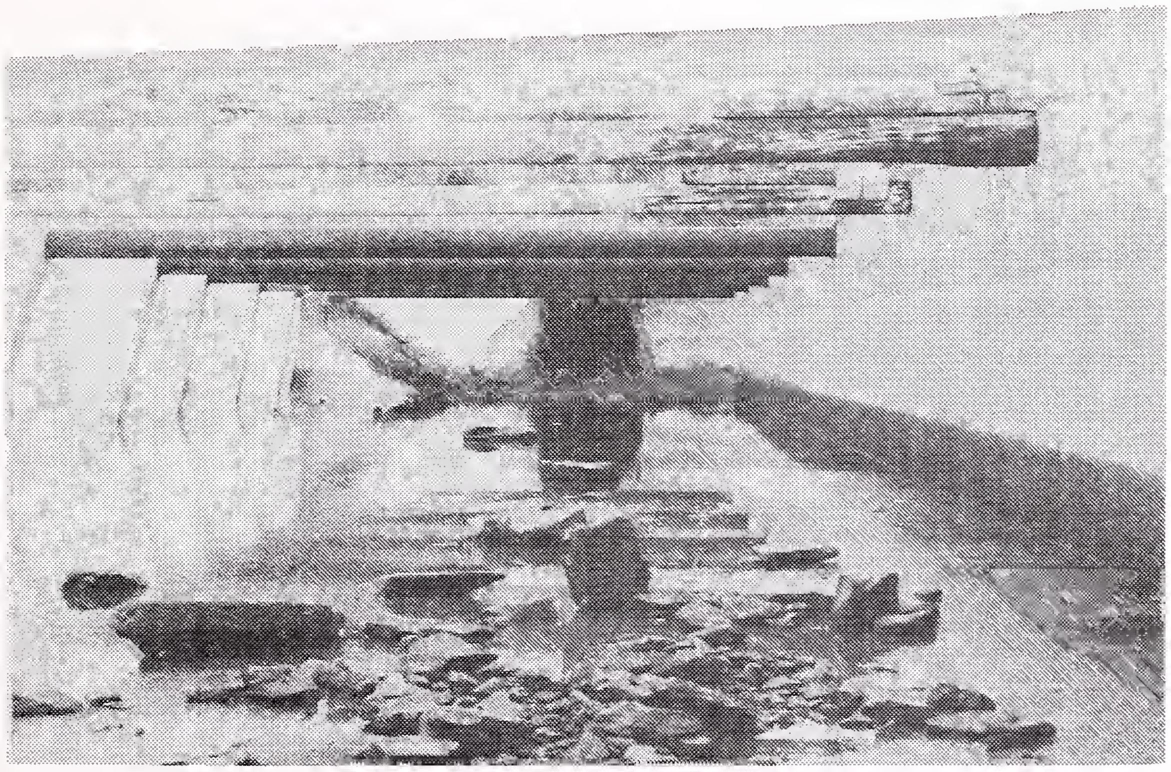
(PHOTO 1) DAM AND RESERVOIR



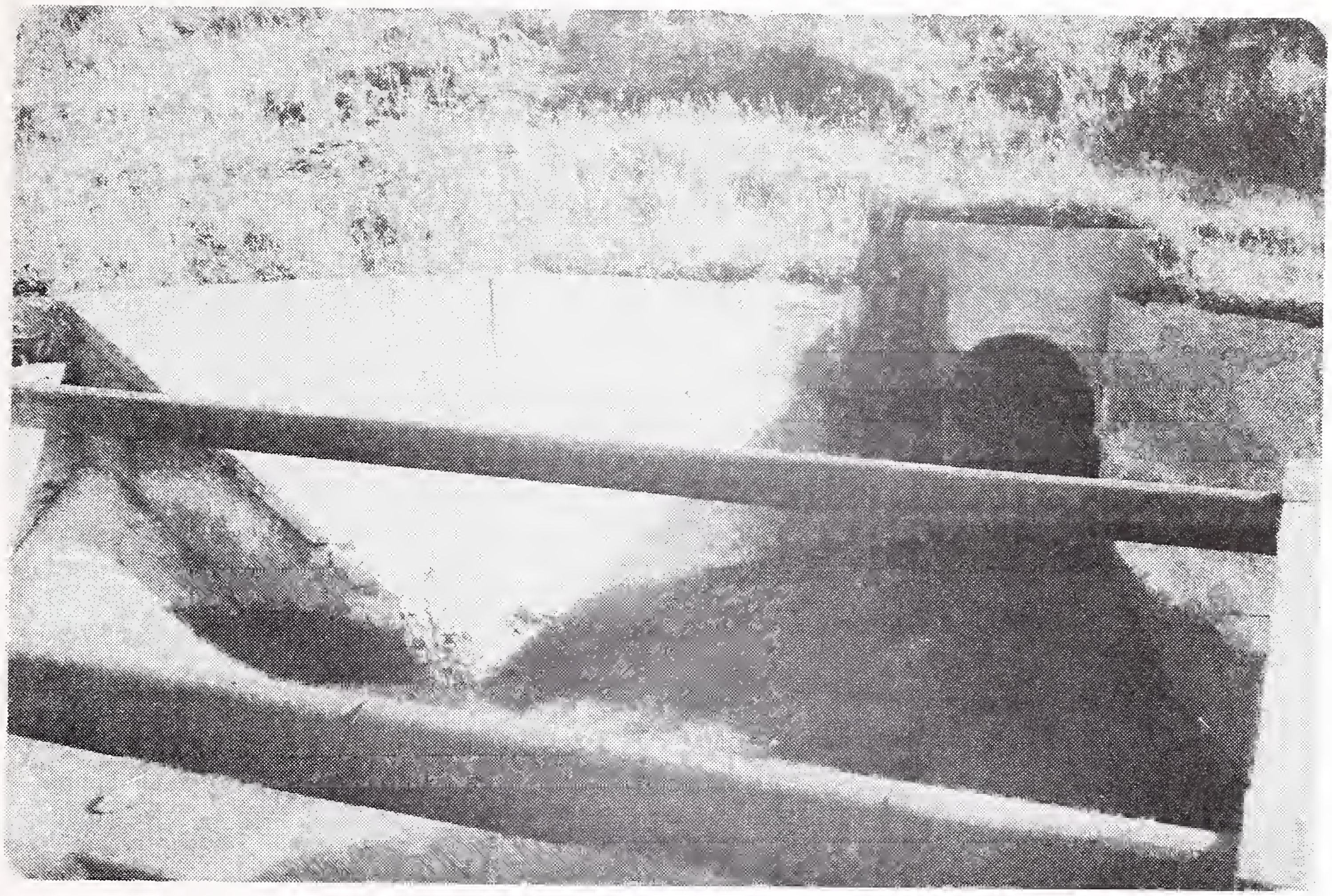
(PHOTO 2) CONTROL TOWER, DOWNSTREAM GATE OPEN



(PHOTO 3) LOW LEVEL OUTLET DISCHARGE CHANNEL



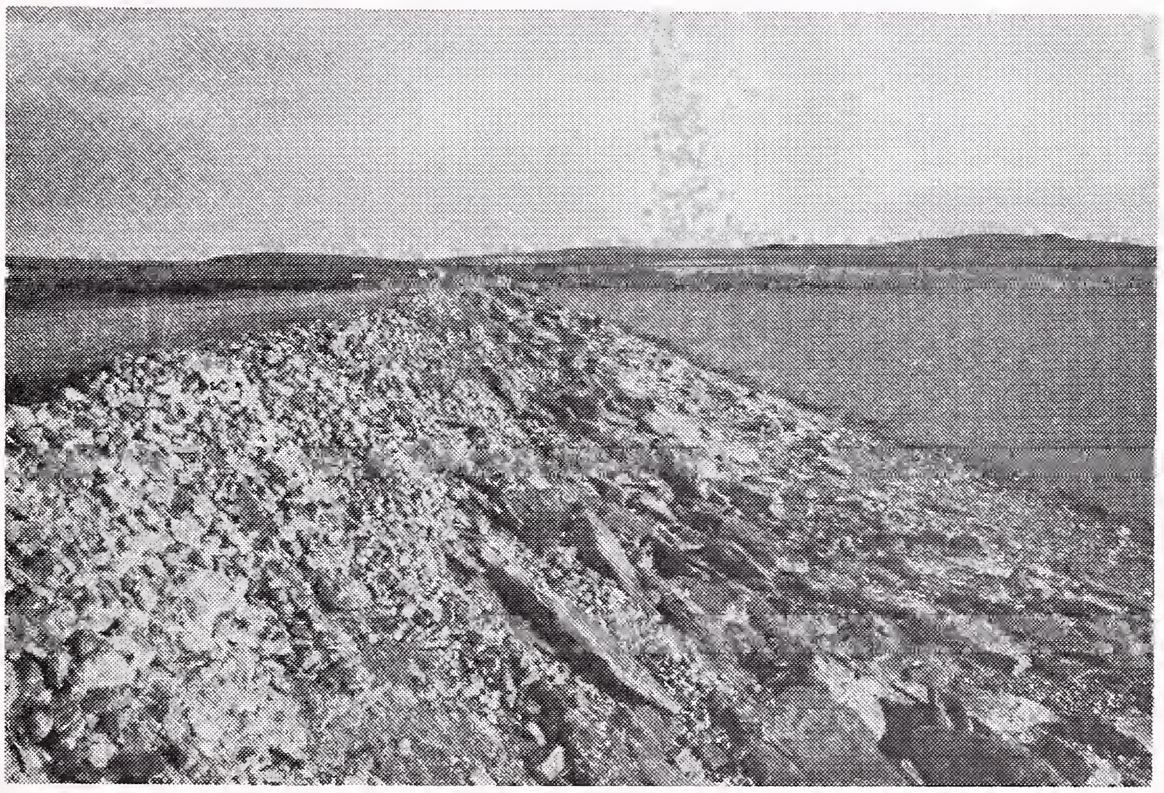
(PHOTO 4) LOW LEVEL OUTLET DISCHARGE CHANNEL--TUNNEL
PORTAL IN BACKGROUND



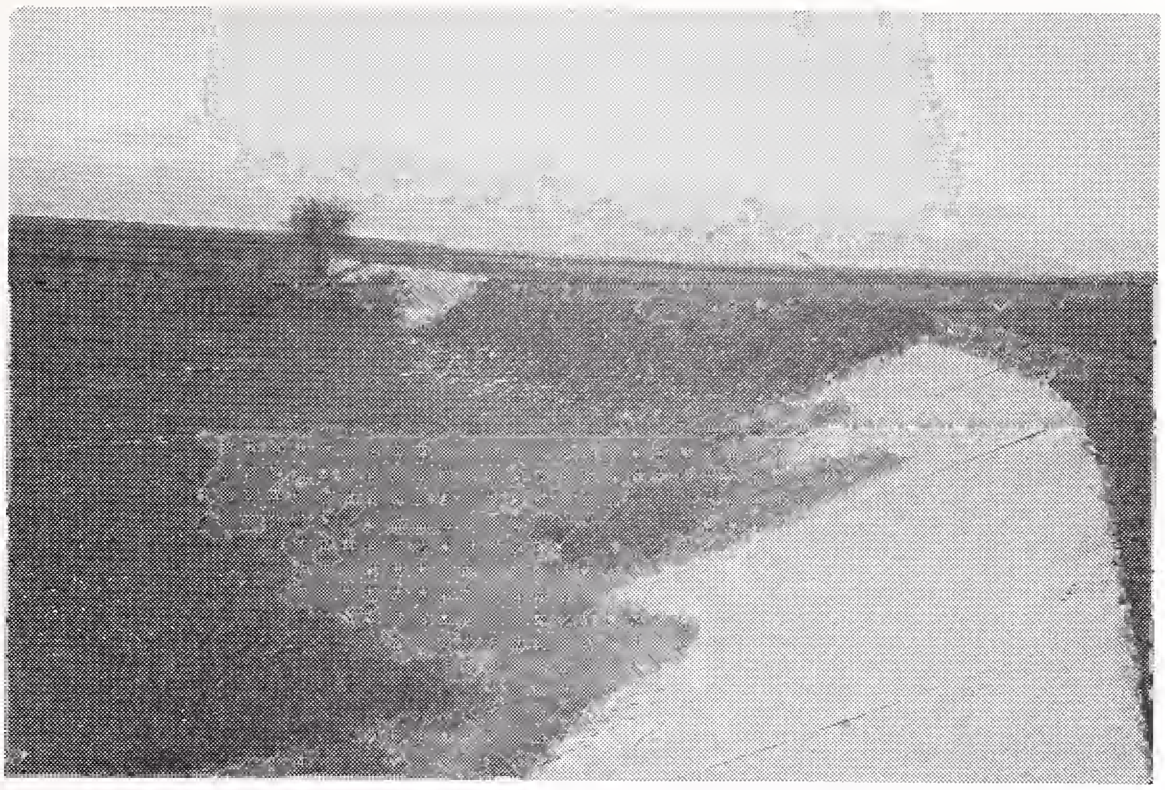
(PHOTO 5) LOW LEVEL OUTLET STRUCTURE. NOTE THE CRACKED AND SPALLED CONCRETE.

(PHOTO 6) MAIN DAM (EASTERN) EMBANKMENT DOWNSTREAM SLOPE

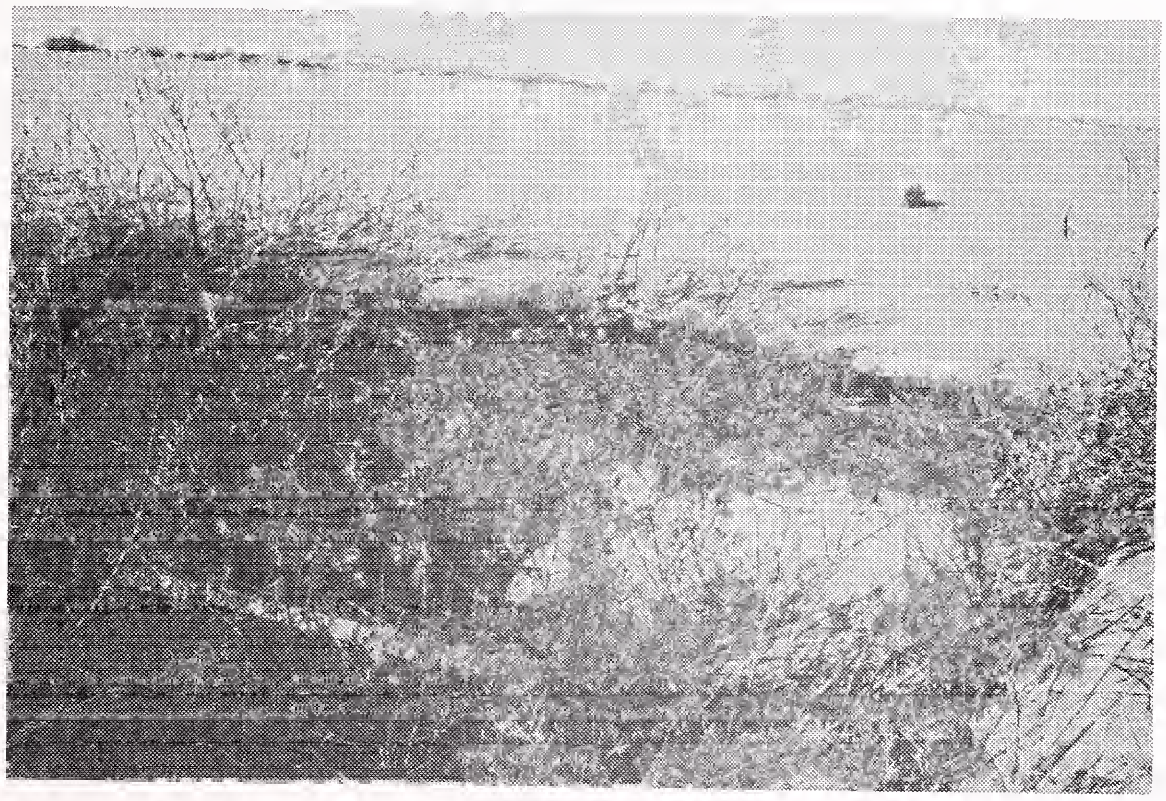
(PHOTO 7) WESTERN EMBANKMENT DOWNSTREAM SLOPE



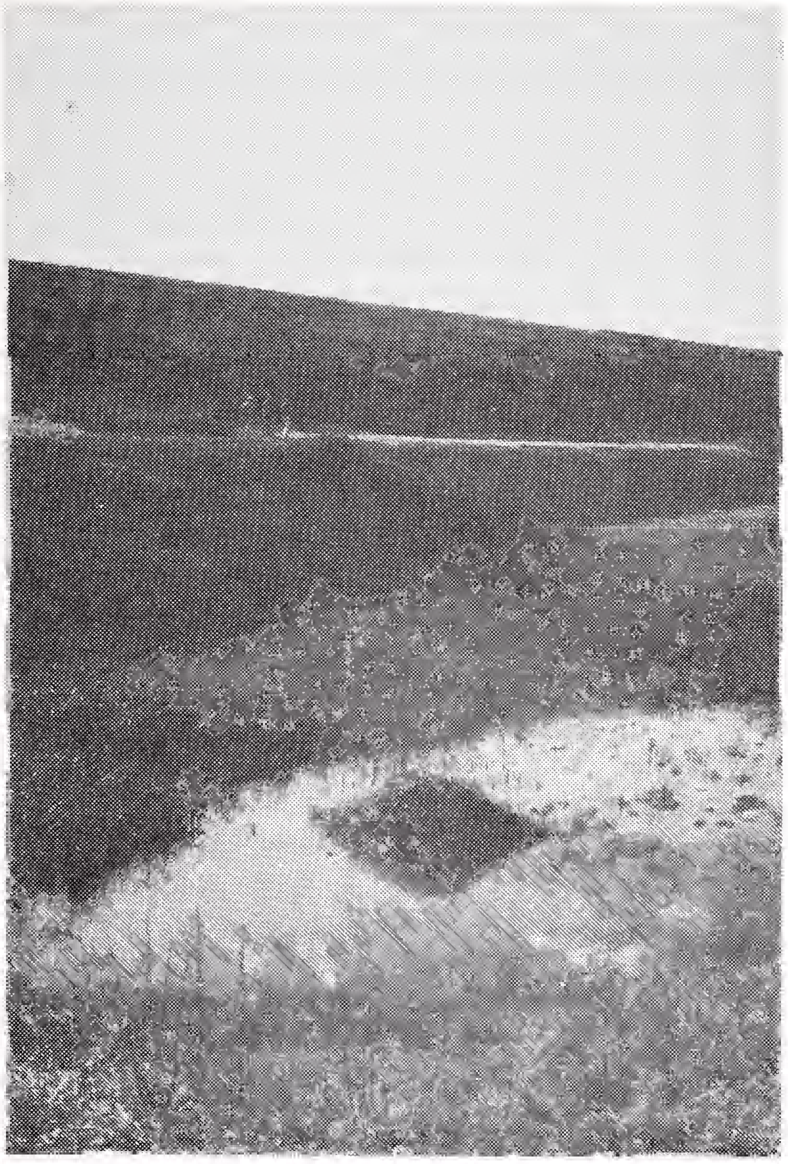
(PHOTO 8) MAIN DAM EMBANKMENT UPSTREAM SLOPE



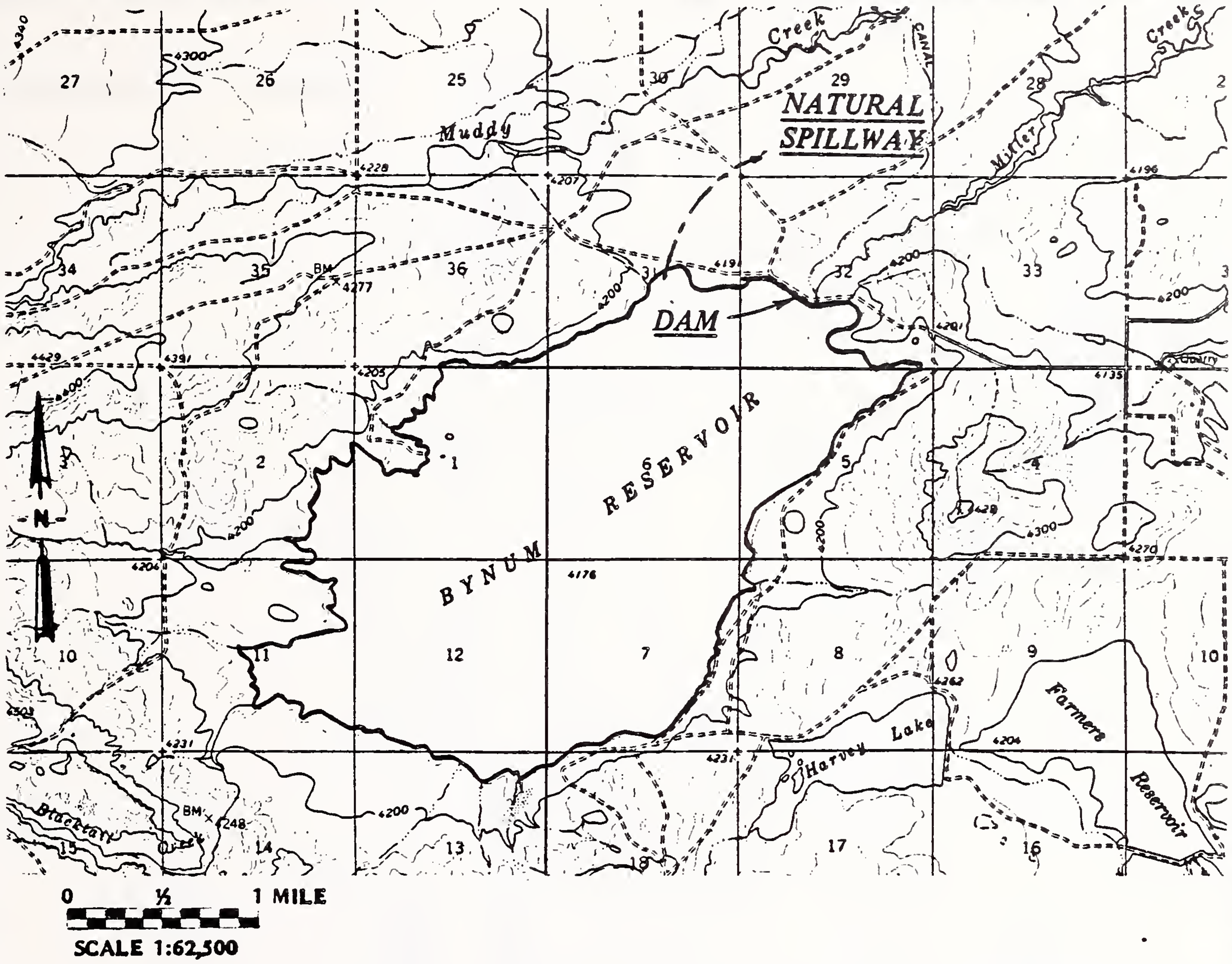
(PHOTO 9) WESTERN EMBANKMENT UPSTREAM SLOPE



(PHOTO 10) WESTERN EMBANKMENT EROSION IN UPSTREAM GUNITE SURFACE



(PHOTO 11) PONDING WATER (SEEPAGE) DOWNSTREAM
MAIN EMBANKMENT



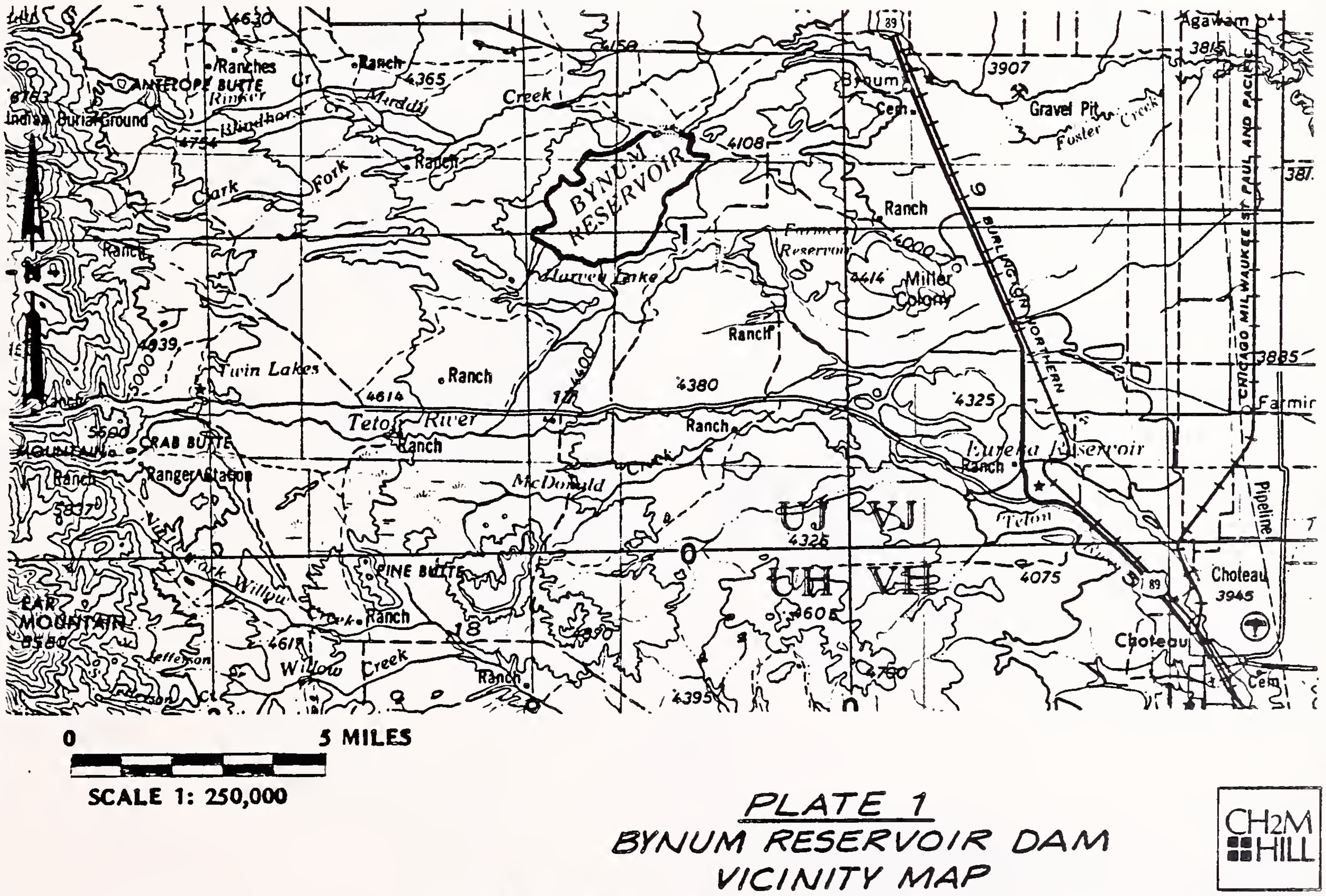


PLATE 1
BYNUM RESERVOIR DAM VICINITY MAP

CH2M HILL

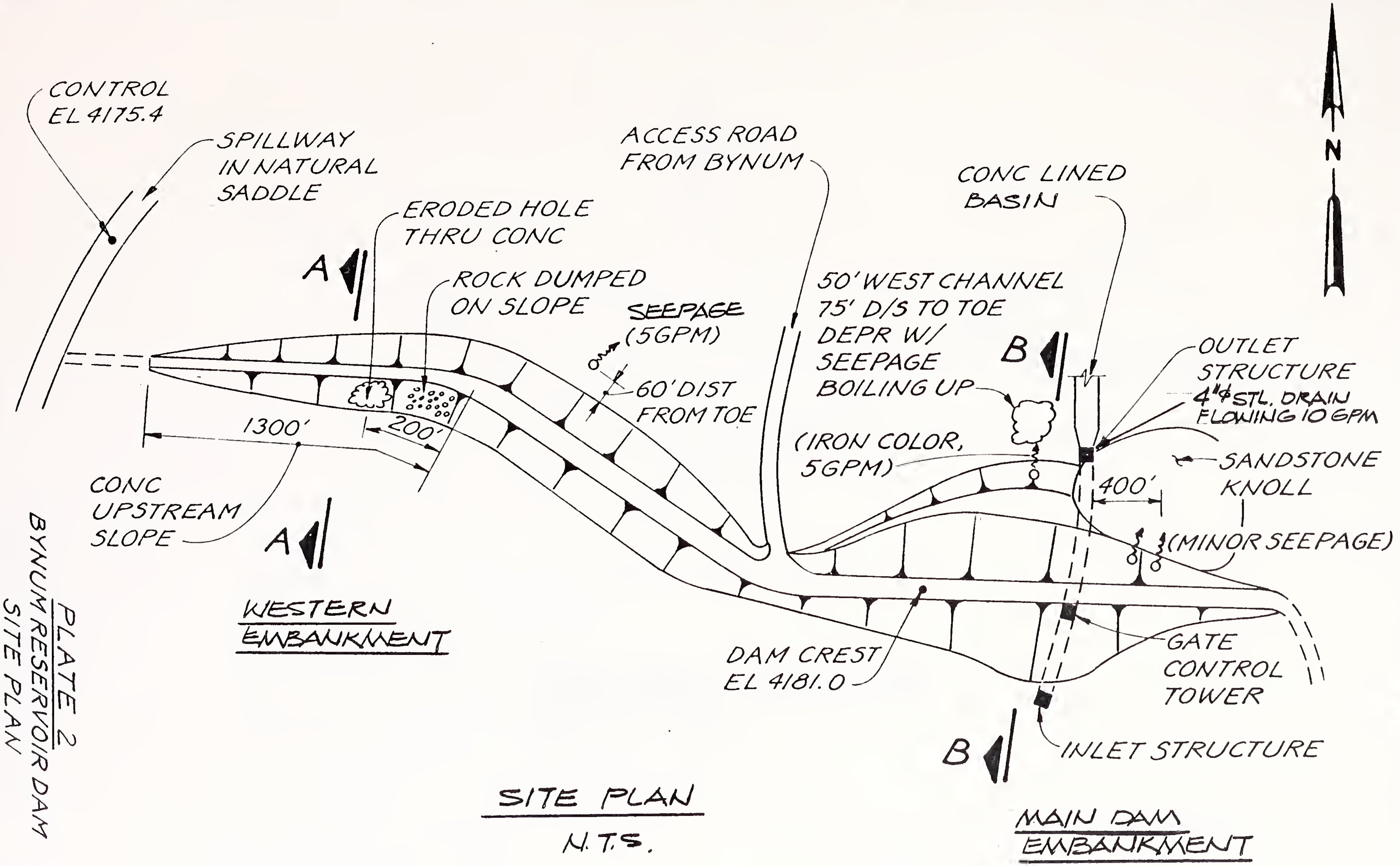
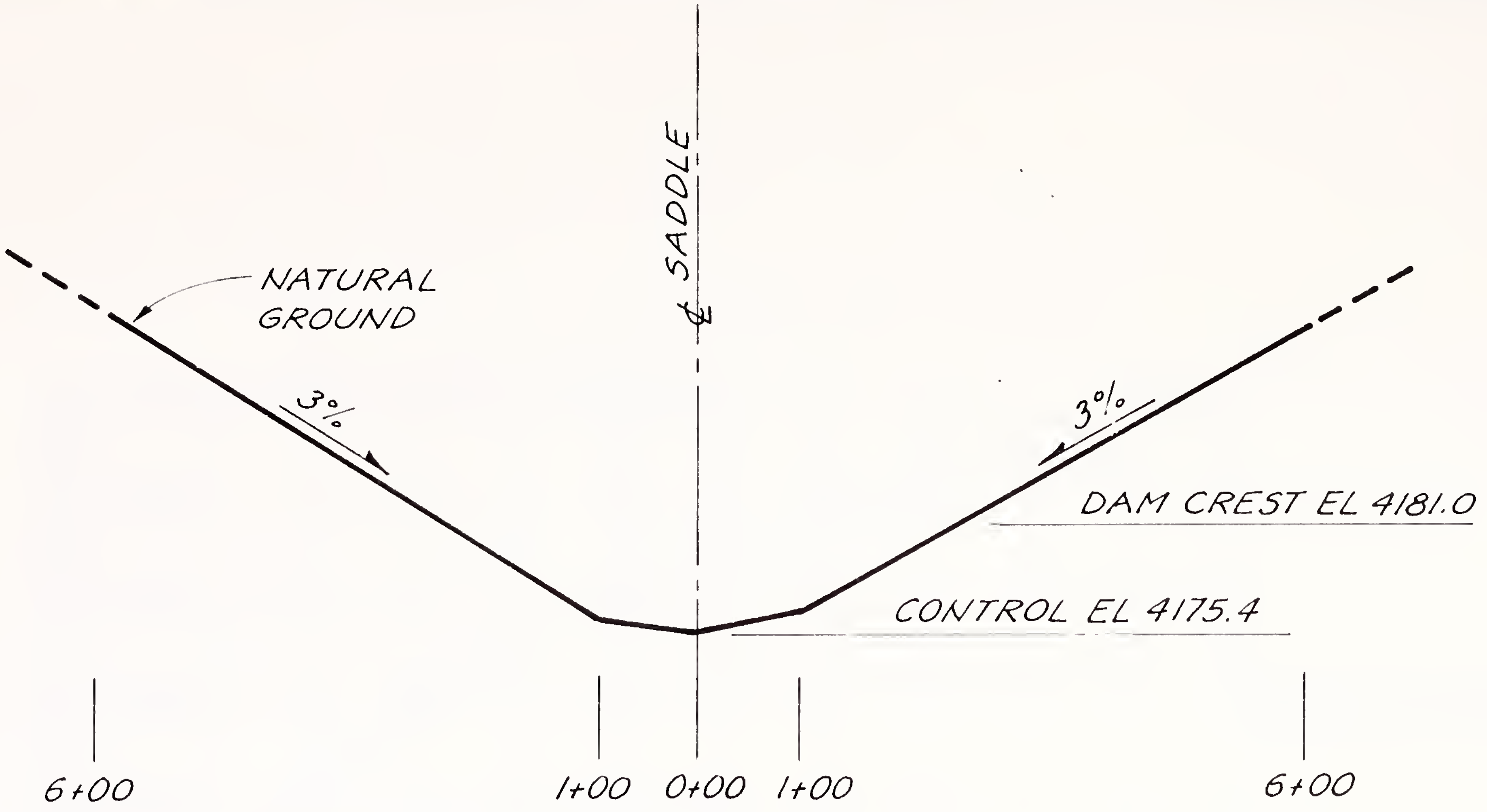


PLATE 2
BYNUM RESERVOIR DAM
SITE PLAN



SPILLWAY SECTION

HORIZ 1" = 200'
VERT 1" = 10'

NOTE: ALL ELEVATIONS ARE BASED ON ASSUMED CONTROL TOWER EL 4185.0 NGVD.

PLATE 3
BYNUM RESERVOIR DAM
SPILLWAY SECTION

BYNUM RESERVOIR
SPILLWAY RATING

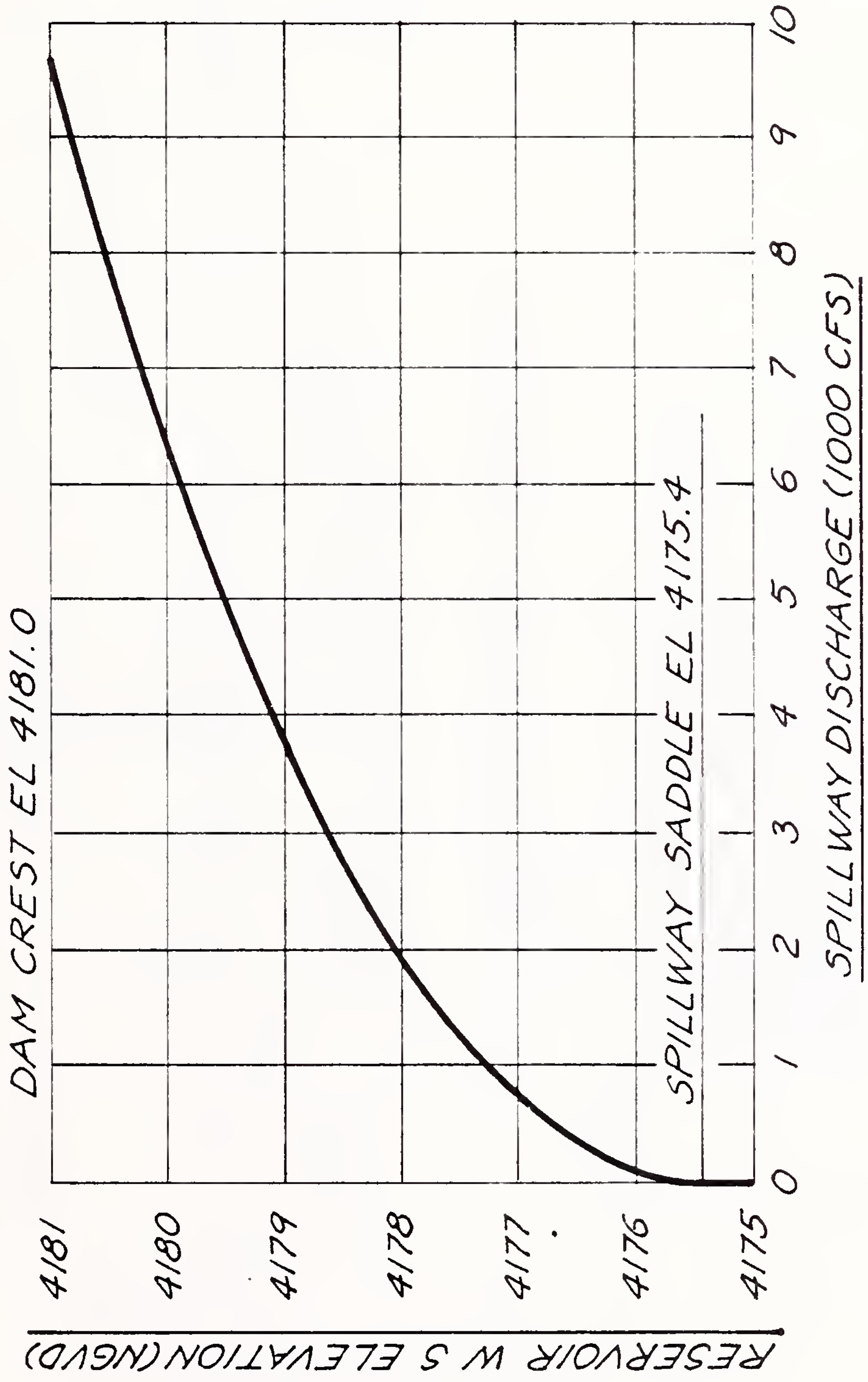
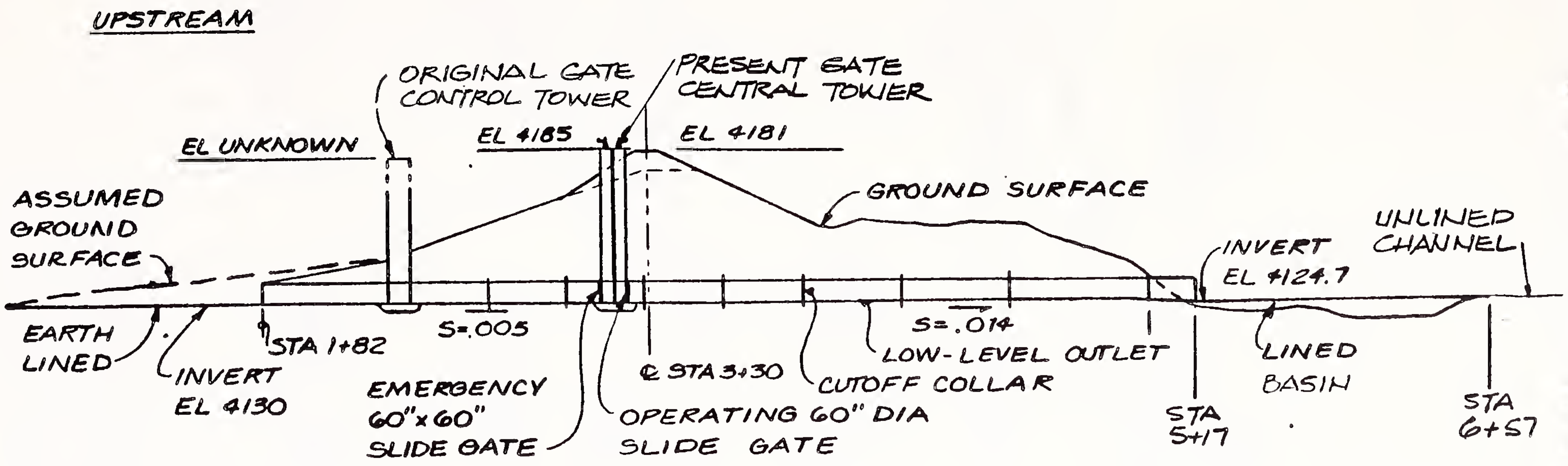


PLATE 4
BYNUM RESERVOIR DAM
SPILLWAY RATING CURVE

CH2M HILL



OUTLET WORKS PROFILE

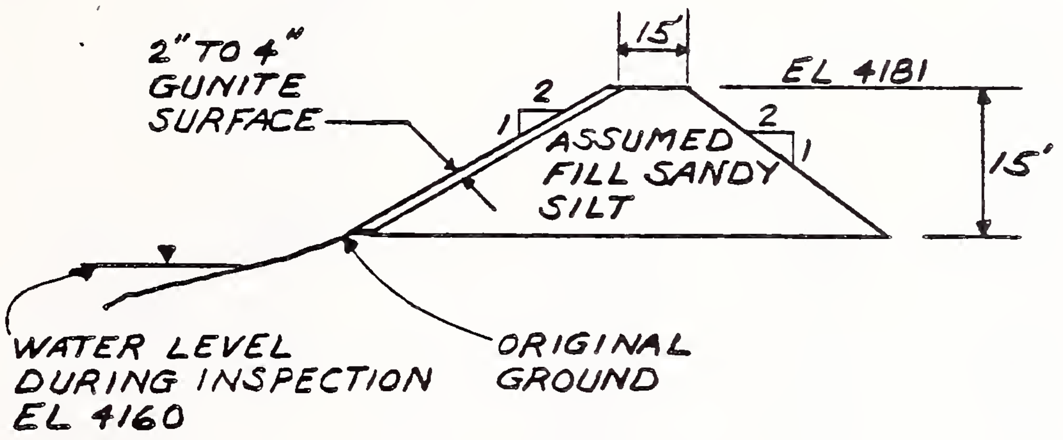
NTS.

NOTES:

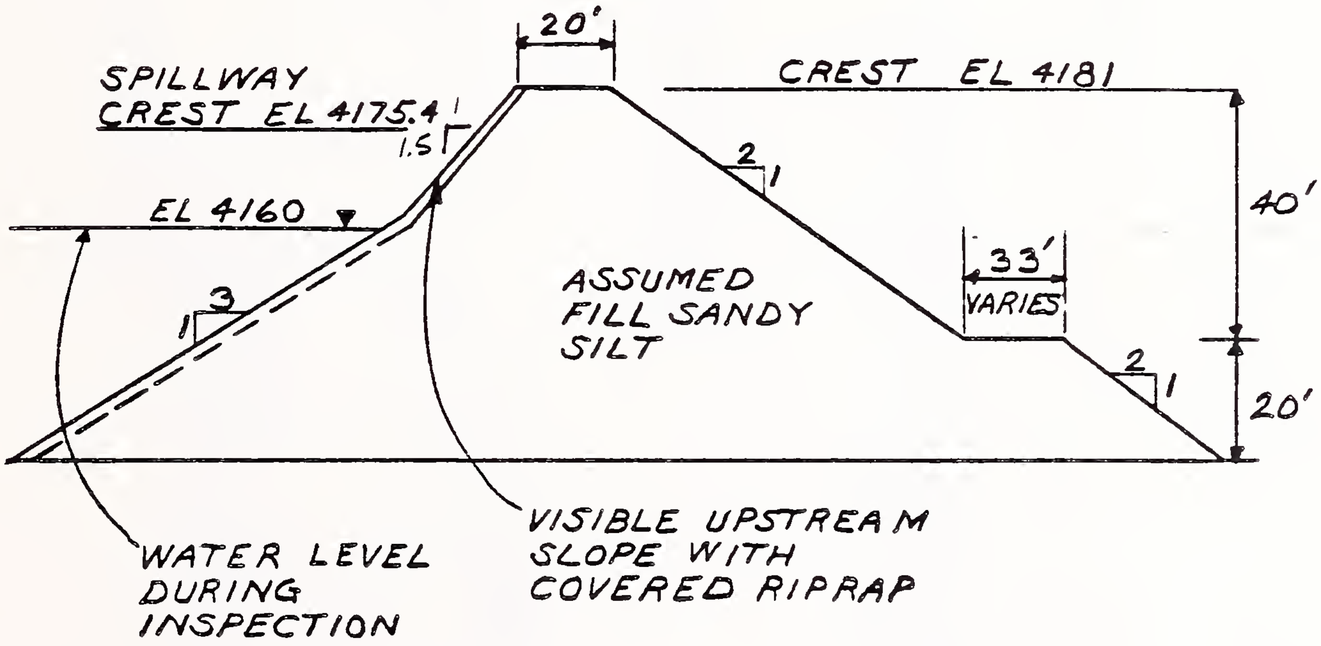
1. TAKEN FROM 1926 DRAWING
2. DAM CREST ELEVATION IS BASED ON ASSUMED CONTROL TOWER ELEVATION 4185 NGVD
3. EMERGENCY & OPERATING GATES AS SHOWN ARE NOT USED IN PRESENT OPERATING PROCEDURES AS TRUE EMERGENCY & OPERATING GATES.

PLATE 5
BYNUM RESERVOIR DAM
OUTLET WORKS PROFILE

CH2M HILL



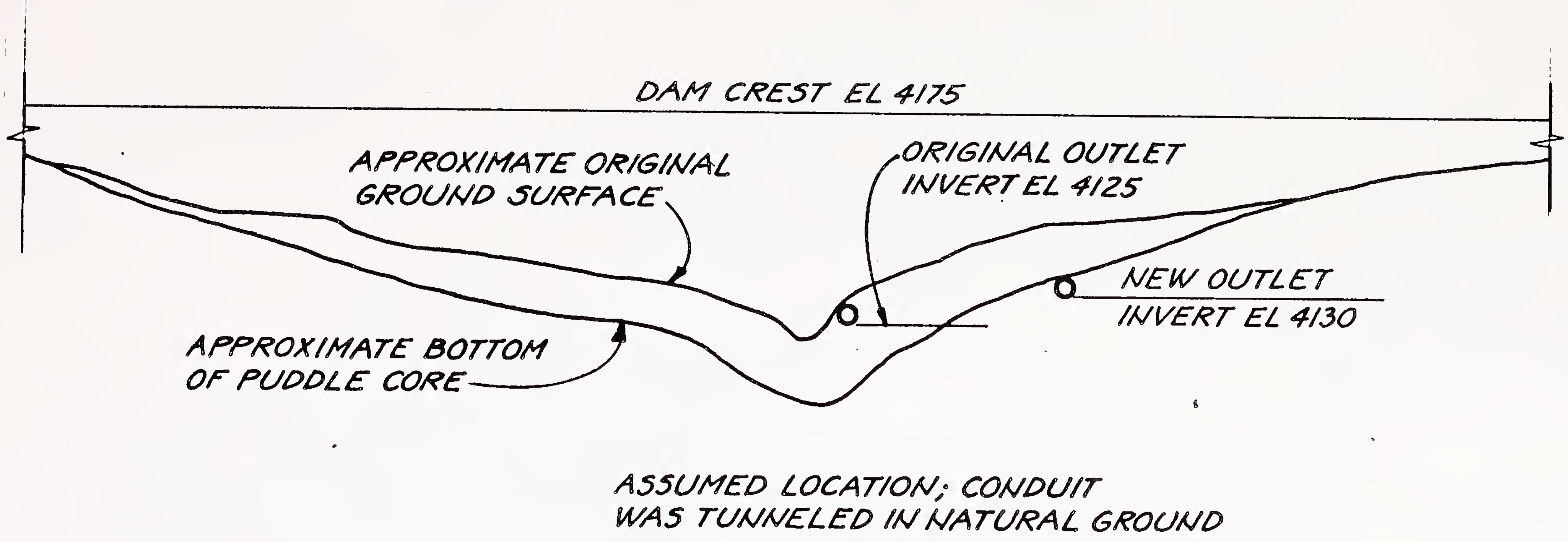
SECTION A
NTS
WESTERN EMBANKMENT



SECTION B
NTS
MAIN DAM (EASTERN)
EMBANKMENT

PLATE 6
BYNUM RESERVOIR DAM
EMBANKMENT SECTIONS

CH2M
HILL


DAM CREST EL 4175
APPROXIMATE ORIGINAL GROUND SURFACE
ORIGINAL OUTLET INVERT EL 4125
NEW OUTLET INVERT EL 4130
APPROXIMATE BOTTOM OF PUDDLE CORE
ASSUMED LOCATION; CONDUIT WAS TUNNELED IN NATURAL GROUND

MAIN DAM EMBANKMENT PROFILE

NTS

NOTE: TAKEN FROM 1915
DRAWING DEVELOPED
FROM TESTIMONY
MADE 1911.

PLATE 7
BYNUM RESERVOIR DAM
MAIN DAM EMBANKMENT PROFILE